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ABSTRACT

Defence personnel working in the heat run the risk of heat illnesses and decreased performance due to hypohydration. Physiological, psychological and mechanical methods for improving the intake and absorption of water into the body are discussed. Recommendations include evaluation of the effectiveness and service suitability of 'bladder' style delivery systems, and water bottles with push/pull tops such as those used on some sports bottles, consideration of the inclusion of 'sports drinks' into ration packs, and studies on hyperhydration.

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Executive Summary

Defence personnel working in the heat run the risk of heat illness and decreased performance due to dehydration. This problem is likely to be exacerbated as the Army's presence increases in northern Australia.

In the heat, sweating is the only physiological mechanism for dissipation of the heat produced as a result of physical work. This can be done only at a cost to the body's water reserves.

Critical factors which are considered in this review include physiological, psychological and mechanical aspects. The risk of heat illness will be minimised only if each of these aspects is adequately addressed.

The report recommends the inclusion of sports drinks in ration packs - subject to studies on their impact on water sterilizing tablets. They have physiological advantages in that they may increase the uptake of water into the body and supply a readily available form of energy. Palatability and recognition of product are other important aspects of fluid intake. The addition of a recognisable sports drink to the ration pack may result in increased fluid intake due to familiarity with commercially available products.

The mechanics of ensuring adequate water intake by soldiers in the field is an aspect that is not covered in the literature. The present military issue canteen is not easy to use when soldiers are on the move. Two possible alternative methods for increasing fluid intake have been identified. The first is based on a bladder from which fluid can be sucked using a flexible tube. This tube could be located conveniently near the mouth for ease of use. The second alternative would be a modification of the present canteen based on those 'sports bottles' that have a push down cap which can be pulled open with the teeth.

DFSC is collaborating with the Army Technology and Engineering Agency (ATEA) and with AMRL -Queensland to investigate improved systems of water delivery.

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Contents

1. Preamble

Three states of hydration of the body are recognised. These are:
1. Euhydration or the normal state of hydration
2. Hypohydration or negative level of hydration
3. Hyperhydration or a positive level of hydration.

Euhydration is necessary for optimal physical performance whereas hypohydration can lead not only to performance degradation but, if severe enough, will cause total incapacitation, injury and even death. The process by which a state of hypohydration is achieved is 'dehydration'. Technical Panel 8 of The Technical Cooperation Program (TTCP), whose function is to identify substances and procedures that enhance or maintain physical performance, has published a draft application paper on oral hydration drinks (TTCP, 1995). This review looks at the issues behind that paper and at potential ways of increasing water intake through alternative delivery systems.

2. Introduction

Depending on body fat level, between 50% and 65% of the human body normally consists of water (Passmore and Eastwood, 1986, p. 9). Water constitutes 65 to 75% of the weight of muscles and less than 25% of the weight of adipose tissue. The two compartments of water in the body are intracellular (inside the cell) and extracellular (outside the cell). The extracellular fluid includes the blood plasma and lymph, saliva, fluids in the eyes, fluids excreted by glands and the intestines, fluids that bathe the nerves of the spinal cord, and fluids excreted from the skin and kidneys. Intracellular water accounts for about 62% of the total body water with 38% normally being located extracellularly (McCardle et al, 1991, p. 60).

Water acts as the transport and reactive medium in the body. Diffusion of gases always takes place across surfaces moistened by water. Nutrients and gases are transported in aqueous solution and waste products leave the body through the water in urine and faeces. Water also plays a large part in thermoregulation since it can absorb a considerable quantity of heat with only a small change in temperature (McCardle et al, 1991, p. 61).

An individual's water intake and output are generally relatively stable over time and the body can under normal circumstances adjust to imbalances where the output exceeds the input. The normal daily water balance is shown in Table 1.

As can be seen from Table 1 the sources of water for intake are food and fluids. When foods are metabolised carbon dioxide and water are formed. This water is known as metabolic water. Water is lost to the body as urine, in faeces, through the skin and in expired air. The largest volume of water is lost via urine except when sweat rates are abnormally high. McCardle et al (1991, p. 63) estimates that 15 mL of water are

required to eliminate 1g of metabolic solute such as urea (an end product of protein metabolism). This is one of the reasons that large quantities of protein are not used as an energy source during exercise since this speeds up dehydration. The body is capable of conserving water lost via urine by releasing vasopressin or anti-diuretic hormone to increase water absorption in the kidneys (McCardle et al, 1991 p390).

*Table 1: Daily water balance**

Daily water input		Daily water output	
Source	Volume (mL)	Source	Volume (mL)
Food	1000	Urine	1500
Fluids	1200	Faeces	100
Metabolism	350	Skin - insensible perspiration - sweat	 350 250
		Lungs	350
Total	2550	Total	2550

* Source: Adapted from McCardle et al, 1991 p.62.

Table 1 represents the daily water balance at minimal resting rate of an average individual. About 350 mL of water is lost per day as insensible perspiration, ie water that seeps from the deeper tissues to the surface of the skin. Active sweating is controlled by the sweat glands. Evaporation of sweat provides one mechanism to cool the body.

The volume of water that can be lost each day via sweating is of the order of 8 to 12 litres in a hot environment, during prolonged exercise. The marathon runner Alberto Salazar is estimated to have had a sweat rate of 3.7 L per hour in the 1984 Olympic marathon (Burke, 1995a).

The most serious consequence of profuse sweating is the loss of body water and consequently a loss of thermal regulation. The body can only tolerate a rise in body core temperature of about 4°C. If body temperature exceeds 41°C life threatening heat stroke will occur (Howorth, 1995).

Heat is gained directly from the reactions of energy metabolism and also absorbed from the environment by solar radiation and from objects that are warmer than the body (McCardle et al, 1991, p. 547). Heat is lost by the physical mechanisms of radiation, conduction, convection, and the vaporisation of water from the skin and respiratory passages. Circulatory adjustments provide the 'fine tuning' for thermoregulation. When internal heat becomes excessive, peripheral vessels dilate and warm blood is channelled to the cooler surface where heat exchange takes place. An inherent competition exists between mechanisms that maintain a large muscle blood

flow and those that provide for adequate thermoregulation. This is particularly important during exercise in hot weather.

Evaporation via the respiratory passages and the skin is the primary mechanism for protection against overheating. The effectiveness of the other means of heat loss, radiation, convection and conduction decreases as the ambient temperature approaches body temperature. When ambient temperature exceeds body temperature a net body heat gain will result. In this case evaporative loss is the only mechanism for heat dissipation.

Exercise in the heat imposes two competitive demands on the body: (1) the muscles require oxygen to sustain energy metabolism and (2) metabolic heat must be transported by the blood from the deeper tissues to the periphery. Consequently this blood cannot deliver its oxygen to the working muscles. Since sweating is the only mechanism for heat dissipation, this can only be done at a cost to the body's water reserves held in the extracellular spaces or plasma. As sweating proceeds a relative state of hypohydration occurs and with excessive sweating there may be serious fluid loss and an accompanying reduction in plasma volume. This can lead to circulatory failure and core temperatures may rise to lethal levels (McCardle et al, 1991 p. 556).

3. Heat Illness

Bauman (1995) describes several types of heat illness. The first is heat syncope or fainting, which is acute and seldom serious. Another type is heat oedema, related to salt and water retention. More serious types of heat illness are heat exhaustion (sunstroke) and heatstroke; these are not discrete conditions since they occur along a continuum.

Two types of heat exhaustion are reported. The first is associated predominantly with water depletion and the second with salt depletion which tends to occur in untrained individuals. The usual pattern is mixed water and salt depletion with raised body temperatures most commonly accompanying these effects.

Two variants of heatstroke are recognised. 'Classical heatstroke' often follows several days of exposure to high temperatures with eventual failure of the sweat mechanism. This occurs most often among the very young or very old. More acute forms of heatstroke are often associated with physical activity. The key issue in exercise induced heatstroke is that it may occur among otherwise healthy people, who may continue to sweat. It is an acute and often serious condition with consequences which include significant risks of muscle damage, central nervous system disturbances and coma, hypoglycaemia, acute renal failure and death.

Recognition of the signs and symptoms of heat illness/injury in the field is discussed in Defence Instructions [General] PERS 16-9 (Anon, 1995) and by Compton et al (1991).

4. Fluid Replacement

How then do we counter these problems of dehydration? The belief that restricting fluid intake during training can, in some ways, assist in subsequent work in the heat has no substance in fact (McCardle et al, 1991 p. 561). The most effective defence against heat stress is adequate hydration. The primary aim of fluid replacement is to maintain plasma volume so that circulation and sweating can progress at optimal levels. Indeed the push in recent years is to hyperhydrate prior to exercise to offset the loss of fluids due to sweating.

Another aspect of dehydration is the effect on the ability of the body to do work or exercise. When fluid loss is 2% of the total body weight, work ability is decreased. When it reaches 4-5% of total body weight, there is a 20 - 30% decrease in endurance capacity (Halpern, 1994).

There are three aspects of effective fluid replacement: (1) physiological, (2) psychological and (3) mechanical and these are considered below.

4.1 Physiological aspects

If one could match fluid loss during exercise in the heat with an equal volume of intake there would be little problem. This is of course difficult to achieve. In a normally active subject, drinking begins when dehydration has reduced body weight by about 0.8% (Greenleaf, 1994). The delay in drinking during dehydration has been termed 'voluntary dehydration' although Greenleaf (1994) would argue that it would be more appropriately termed 'involuntary dehydration' or 'involuntary hypohydration' because the delay in drinking is not cognitive.

Two theories have been advanced to explain voluntary dehydration. The first contends that the thirst mechanism stimulus is simply insufficient. This stimulus is regulated by serum osmolality and plasma volume. The second is negative alliesthesia or the development of an unpleasant stimulus engendered by drinking (Szlyk et al , 1989).

Water must be cleared from the stomach before it can arrive at the small intestine, where it is absorbed into the extracellular spaces or plasma and hence available for the sweating mechanism. There are thus two major aspects which control fluid intake. The first is the rate at which fluid can leave the stomach (gastric emptying or GE). The second is the rate of absorption of fluid in the small intestine.

4.1.1 Gastric Emptying

Cold fluids are emptied from the stomach faster than fluids at body temperature (Costill and Saltin, 1974). The volume of the fluid in the stomach is also of importance because GE speeds up for increases in gastric volume up to about 700 mL (Noakes

et al, 1991). Thus to obtain a high rate of absorption, the stomach should remain partially filled and the ingested fluid should be relatively cold.

4.1.1.1 Carbohydrates

The osmolality or number of particles in solution and its effect on GE has been a major consideration by many researchers. It was generally believed in the mid 1970s that sports drinks containing more than 2.5% carbohydrate (CHO) delayed GE and promoted gastric secretion leading to impaired thermal and circulatory functions (Gisolfi and Ryan, 1995).

It was from this aspect that researchers suggested the use of glucose polymers (eg maltodextrin) to replace the simple sugars. By using polymers, the same energy value can be available in a drink at a lower osmolality and hence the GE should be less affected. Mitchell et al (1988) showed that during exercise, consumption of a drink containing 7.5% glucose polymer every 15 minutes did not appear to inhibit GE.

Gisolfi and Ryan (1995) are of the opinion that the way in which GE is measured influences the conclusions on the effect of osmolality. This may explain some of the conflicting results reported below.

Despite the use of different measuring techniques to the 1970s the evidence on carbohydrate influence on GE is still equivocal.

Vist & Maughan (1994) found that a 2% glucose solution had no effect on GE compared with water, but after the first 10 min of rapid emptying, glucose solutions at a concentration of 4% or more delay GE.

Also the way in which data is expressed by researchers influences the conclusions as discussed by Murray et al (1994). They compared water and 6% solutions of glucose, sucrose, maltodextrin, and sucrose plus glucose. When GE was expressed as a percentage of initial beverage volume remaining in the stomach, the glucose and maltodextrin beverages exhibited significantly lower emptying characteristics; there were no differences in this measure among water, sucrose, and sucrose plus glucose. Similar results were noted when changes in gross gastric volumes were compared. However, when the results were expressed as mean gastric emptying rates, few differences were noted amongst carbohydrate types.

Fructose apparently has a lesser inhibitory influence than glucose on GE (Gisolfi & Ryan, 1995). This may be explained by the glucose receptor located in the duodenum that elicits a strong inhibitory feedback over GE (Lin et al, 1993).

Other research using different measuring techniques to those of the 1970s has led to the conclusion that little difference exists between the GE of water and of beverages containing as much as 10% glucose or 10% glucose polymer (Owen et al, 1986). Levine et al (1991) found no significant difference between the GE of water and 2.5% CHO

during moderate intensity exercise with moderately high sweating rates over a 24 hour period in a simulated military environment. Rehrer et al (1992) studied the GE rate of subjects during prolonged exercise at 70% maximal oxygen uptake (VO_{2max}) with consumption of either water or fluids containing 4.5% glucose, 17% glucose and 17% maltodextrin. They found that water and 4.5% glucose had significantly higher GE rates than the other two treatments. They concluded that CHO concentration was of particular importance whereas type, ie osmolality (eg glucose vs glucose polymer) was found to be of no importance, in terms of GE.

Noakes et al (1991) are of the opinion that osmolality of the fluid consumed does not influence GE rates, as the glucose polymers may undergo near total hydrolysis by the time these solutions reach the glucose receptor in the small intestine. They conclude that it is not the osmolality of the ingested CHO that determines its GE but rather the osmolality of the solution when it is in contact with the receptors that regulate GE.

Gisolfi and Ryan (1995) conclude that, on balance, data over the past two decades support the notion that solutions containing 4-8% CHO, regardless of type (glucose, sucrose, maltodextrins, combinations), do not slow down GE any more significantly than water alone and do not impair thermal or circulatory functions.

4.1.1.2 Electrolytes

The effects of electrolytes on GE have also been studied. Rehrer et al (1993) found no significant effect of potassium or sodium on GE. They had expected, based on preliminary laboratory findings, a specific inhibitory effect on GE of carbohydrate - containing beverages by potassium and a stimulatory effect of sodium. The stimulatory effect of sodium concentration on GE is well described in the literature (Hunt & Pathak, 1960). Rehrer et al (1993), summised that in their study, perhaps the sodium concentration was too low (range 28 - 140 meq/L) relative to the glucose concentration (150 g/L). Therefore the effect of the high carbohydrate concentration to decrease the GE or the effect of the large initial volume to stimulate GE may have overshadowed any specific effect of potassium or sodium. Nielsen et al (1986), when comparing the hydration capacity of various beverages, found that the beverage with the highest potassium concentration was the least successful, based on plasma volume changes. The concentration of potassium (138 meq/L) in Nielsen's study was much greater than the 38 meq/L used by Rehrer et al (1993).

4.1.1.3 Exercise

Exercise appears not to have a major effect on the rate of GE compared to rest when the exercise intensities are below 70% VO_{2max} (Mitchell et al, 1989; Rehrer et al, 1989). Gisolfi and Ryan (1995) have reviewed the literature and concluded that the duration of exercise also does not reduce GE rate. Nevertheless, mode of exercise may influence GE. Costill (1990) reported that running produces greater GE than rest or cycling whereas Houmard et al (1991) could not demonstrate a difference in GE between rest, cycling or running. The effects of training are inconclusive; two studies suggest that

training enhances GE (Campbell et al, 1924; Carrio et al, 1989) while another indicates no effect (Rehrer et al, 1989).

Exercise in the heat can have an effect on GE. Owen et al (1986) showed a reduction in GE at 35°C for exercise at 65% VO_{2max}. Other authors (Neufer et al, 1989; Rehrer et al, 1990) have demonstrated that hypohydration can reduce GE. Gisolfi and Ryan (1995) found that hypohydration equivalent to a loss of approximately 3% of body weight had no effect on GE of 6-9% CHO-electrolyte solutions during 90 minutes of cycle exercise at 65% VO_{2max} in a cool (22°C) environment.

Gisolfi and Ryan (1995) concluded that the stomach functions extremely well during exercise and under adverse environmental conditions. Even following mild dehydration and fatiguing exercise up to two hours in duration, GE was not delayed. Gastric function is impaired and gastrointestinal symptoms emerge only when subjects become severely hyperthermic and hypohydrated to a loss of greater than 4% of body weight.

4.1.2 Intestinal Absorption

Water is primarily absorbed in the proximal small intestine (duodenum and jejunum or duodejejunum); it is a passive process dependent upon net solute absorption. Water transport and homeostasis are highly dependent upon Na^+ absorption. This is a two step process involving passive Na^+ entry across the brush border membrane via simple diffusion or co-transport with other electrolytes (K^+, Cl^-), non electrolytes and by active Na^+ extrusion across the basolateral membrane via the Na^+/K^+ pump. It is generally agreed that CHO stimulates water absorption in the intestine (Gisolfi and Ryan, 1995).

4.1.2.1 Carbohydrates

From perfusion studies in resting condition, Rehrer et al (1992) found that net water absorption was significantly greater for a dilute glucose/salt solution (4.5% glucose; 20 meq NaCl per litre) than for water. They concluded that this may imply an advantage to consumption of fluids containing glucose (or glucose polymer) and sodium during exercise, even when hydration and not CHO provision is the primary objective.

Gisolfi et al (1992) found that isotonic solutions containing up to 6% glucose, sucrose, maltodextrin, or corn syrup solids were similar in their ability to stimulate water absorption from the duodejejunum. However, increasing CHO concentrations to 8% significantly reduced water absorption for solutions containing glucose and corn syrup solids, but not maltodextrins or sucrose. Thus, CHO form seems to exert a stronger influence on intestinal absorption than it does on GE.

The effects of solution osmolality on absorption of replacement solutions in human duodejejunum has been studied by Shi et al (1994). They found that perfusing 6% CHO solutions with osmolalities ranging from 186 to 403 mosmol/kg (ie hypotonic, isotonic

and hypertonic) did not produce significant differences in human plasma volume. Shi et al (1995) found that a solution containing several forms of CHO (thereby potentially activating several transport mechanisms) tends to produce more water absorption than a solution containing only a single form of CHO that activates only one transport mechanism. They recommend 6% CHO-electrolyte solutions containing a combination of free glucose and fructose for maximising water and CHO absorption.

Glucose stimulates the absorption of Na^+ in the small intestine. This is attributed to either glucose- Na^+ co-transport or to glucose-stimulated Na^+ absorption thus setting up an osmotic gradient for water absorption. The optimum ratio of glucose to Na^+ is unclear (Gisolfi and Ryan, 1995).

4.1.2.2 Anions

Anions can have a significant effect on water and salt absorption. Fordtran (1975) found maximal water and Na^+ absorption was with Cl^- followed by HCO_3^- and then SO_4^{2-}. Combining Cl^- and HCO_3^- was not as effective as Cl^- alone.

4.1.2.3 Exercise

The effects of exercise are not well understood and this is an area which warrants further research. Studies using segmental perfusion of the small intestine with fluids to investigate absorption have led to conflicting results. Fordtran and Saltin (1967) found that a 1h cycle of severe exercise had no consistent effect on jejunal or ileal absorption of water, Na^+, Cl^-, K^+, glucose, L-xylose, urea, or tritiated water. Gisolfi et al (1991), studied absorption in 6 trained male cyclists perfused with carbohydrate-electrolyte solutions. They concluded that there was no significant effect of exercise on water absorption, but fluid absorption was significantly greater from 6% CHO-E solution than from water when the data were pooled over rest, exercise, and recovery periods. Whereas Barclay and Turnberg (1988), perfused isotonic saline into subjects performing moderate exercise and found that exercise significantly reduced water, sodium chloride and potassium absorption.

Gisolfi and Ryan (1995) caution that although segmental perfusion studies provide the most precise measurement of water and solute transport, the disadvantage of this technique is that it only evaluates a segment of the intestine. Therefore care must be taken in trying to extrapolate these data to what would occur if these solutions were ingested orally.

4.1.3 Other Considerations

4.1.3.1 Hyperhydration

One way of overcoming voluntary dehydration is to hyperhydrate. Hyperhydration involves raising the level of hydration above that of euhydration by ingesting excess fluid or by using substances (eg. glycerol, vassopressin) to retain body water that

otherwise would be excreted. Hyperhydration prior to exercise in the heat provides some protection because it delays the development of hypohydration, increases sweating during exercise, and brings about a smaller rise in body core temperature (McCardle et al, 1991 p. 561). These authors recommend the consumption of 400 to 600 mL of cold water 10 to 20 minutes before exercising in the heat. They caution against considering that this would replace the need for continual fluid replacement. They also do not consider pre-exercise hyperhydration to be as effective in maintaining thermal balance as consuming a volume of water equal to the water lost during exercise.

Kristal-Boneh et al (1995) found that chronic water loading at double normal intake for one week can have a considerable impact on the time required to complete a task. These authors compared the time required to cycle 15 km by subjects who had been 1) partially dehydrated, 2) hyperhydrated 2 hours before the test (*acute*), 3) hyperhydrated for 1 week prior to the test (*chronic*), 4) control (no treatment). Relative to the control group there was a significant increase in time (7.3%) for the partially dehydrated group, no significant difference for the *acute* group, and a significant decrease in time (10%) for the *chronic* group. Another aspect of their study supported the concepts that heat acclimation and chronic hyperhydration significantly increased the capacity of subjects to perform a physical task in the heat.

Burke (1995b) points out that one of the problems of pre-exercise fluid ingestion is a marked diuresis, particularly if plain water is consumed in large volumes. She suggests that to overcome this problem it may be advantageous to either ingest or infuse saline, although the problems of palatability and practicality limit these options.

Although saline solutions may be impractical as a means of inducing hyperhydration, they may be of some value when used during exercise. Infusion of saline during exercise reduces core temperature, heart rate and sweat rate, while stroke volume and skin blood flow are increased (Murray et al, 1991). The rise in skin blood flow is postulated to promote an increase in radiative heat loss and decreases in sweat rate and oesophageal temperature. Murray et al (1991) conclude that such reductions in cardiovascular and thermoregulatory strain would ostensibly be of benefit to athletes, workers and military personnel who exercise in the heat.

4.1.3.2 Glycerol

Recent work has indicated that the addition of glycerol to a pre-exercise fluid may provide substantial protection against exercise induced hypovolaemia (reduced blood volume), particularly when exercise is conducted in thermally stressful environments. Lyons et al (1990) showed that, compared to plain water, the urine volume prior to exercise was decreased when glycerol was ingested, resulting in glycerol-induced hyperhydration. During the exercise following the glycerol-induced hyperhydration, there was elevated sweat rate and lower rectal temperature.

Murray et al (1991) studied glycerol ingestion during exercise and concluded that there are no substantial metabolic, hormonal, cardiovascular or thermoregulatory advantages to the consumption of solutions containing 4% or 10% glycerol.

Greenleaf et al (1994a) incorporated glycerol (5%) into a high CHO (19%) solution. This solution was ingested during the rest and exercise phases of the study. No effect of glycerol on plasma volume was found during rest or exercise.

The use of glycerol as a hyperhydration adjunct is a technique which warrants further investigation.

4.1.4 Sports Drinks

In the discussions above the advantages or lack of disadvantages of having CHO present in the replacement fluid have been addressed from the aspect of fluid replacement. There are also advantages to supplying CHO as an additional fuel especially where it will maintain blood glucose levels that would otherwise decline late in exercise, eg. in prolonged moderate-intensity exercise (Coyle, 1991, Coggan and Swanson, 1992). Coyle (1991) recommends that CHO intake begin well before the onset of glycogen depletion and fatigue, and preferably be ingested continually during the exercise.

Burstein et al (1993) investigated the hydration status of subjects on a four day march supplied with either tap water or Exceed (7.2% glucose polymer/ fructose). No significant difference between the hydration status of the subjects was found but higher blood glucose levels were maintained in the subjects taking Exceed.

Stable isotope technology was used by Janghorbani (1987) to study the rate of water absorption from 'Gatorade' - a carbohydrate/electrolyte drink - and from plain water. It was tentatively concluded that the rate of absorption of water from Gatorade did not differ consistently from that of water.

While the addition of electrolytes to a replacement fluid may be of no direct benefit to most exercising subjects the sodium provided in most commercially available 'sports drinks' (10 - 25 mmol/L) seems unlikely to cause any disadvantages. The advantages of sodium in enhancing intestinal absorption have already been discussed. It has been reported that the inclusion of either sodium or potassium in a rehydration fluid promotes greater fluid retention by reducing urine output (Maughan et al, 1994). Other evidence suggests K^+ may inhibit GE as discussed in 4.1.1.2.

Meyer et al (1995) investigated the electrolyte balance of children exercising in the heat. They were given either water or 6% CHO drink containing 0, 8.8 or 18.5 mmol of Na^+ per litre. It was concluded that electrolyte, as given in the trial, did not affect electrolyte balance, thermoregulatory responses, or aerobic performance of children exercising in the heat.

Greenleaf et al (1992) found that fluid formulations containing sodium compounds at near isotonic concentrations were more effective than more dilute solutions for restoring and increasing plasma volumes in resting, hypohydrated men. By contrast they found that during exercise at 71% VO_{2max} both isotonic formulations and the more dilute sodium formulations were effective in maintaining plasma volume.

In a further study, Greenleaf et al (1994b) studied the effect of acute hyperhydration on the endurance of subjects undergoing high intensity exercise (87-91 % VO_{2max}). The treatments were:

1) high electrolyte (164 meq Na+ per litre), no CHO, lower osmotic concentration (253 mOsm/kg H_2O);
2) low electrolyte (55 meq Na+ per litre), CHO (9.7%), higher osmotic concentration (365 mOsm/kg H_2O);
3) nil hydration fluid.

They found higher endurance with fluid 1 than with either of the other two treatments. They concluded that reduced endurance with treatments 2 and 3 could not be attributed to change in perceived exertion, exercise metabolism, blood flow, rectal temperature or mean skin temperature. The greater endurance with treatment 1 was probably facilitated by noncarbohydrate factors related to the significant increase in pre-exercise plasma volume. In a precursor to this study Greenleaf et al (1994a) had found that drink composition may be more important than drink osmolality for increasing plasma volume at rest and for maintaining it during exercise.

Burke (1994 p. 350) counters the 'lay' view that sports drinks are too salty and may increase the risk of hypertension. She observes that the sodium level of 10 - 25 mmol/L is comparable with other common fluids such as milk (20 mmol/L) and does not pose a significant risk for most athletes.

Lamb (1994) also suggests that there is little direct evidence for a beneficial effect of electrolyte replacement for any but a small proportion of endurance athletes. However there have been reports of athletes who participate in very prolonged exercise experiencing severe hyponatraemia (low plasma sodium concentration). He concludes that conceivably, ingestion of electrolyte beverages by soldiers sensitive to the development of hyponatraemia could be effective in eliminating or reducing the severity of hyponatraemia.

4.1.5 Composition of Sports Drinks

Table 2 shows the composition of some commercially available sports drinks. The carbohydrate content of these drinks lies within the acceptable range of 4-8% as recommended by Gisolfi and Ryan (1995) with the exception of Solo Sport. Again with the exception of Solo Sport the drinks use combinations of carbohydrates. As previously noted this has been found to increase fluid absorption (Shi et al, 1995). Sodium and potassium are both included for the reasons previously detailed, with the sodium levels being within the range considered acceptable by Burke (1994). The

addition of magnesium and calcium would appear to be of no significance to increasing fluid intake or increasing performance. The inclusion of chloride in Exceed may assist in fluid absorption (Fordtran, 1975).

Table 2: Composition of some commercially available 'sports drinks'.

Nutritional Information per 100 mL	Gatorade	Adams ale	Iso Sport	Sport plus	Solo Sport	Powerade	Exceed	Vitasport
Energy (kJ)	105	105	121	120	174	134	117	125
Protein (g)	0	0	0	0	0	0	0	0
Fat (g)	0	0	0	0	0	0	0	0
Total Carbohydrate (g)	6	6	7	6.9	10	8	6.8	7.8
--Sucrose (g)	3	3	3	4.9	10	6	0	2.5
--Glucose (g)	1.7	1.7	1.7	2	0	0	0	2.6
--Fructose (g)	1.3	1.3	1.3	0	0	0	2.4	0
--Glucose Polymers (g)	0	0	1	0	0	2	4.4	2.7
Sodium (mg)	41	16.3	41	36.6	34.7	25	20	44
Sodium (mmol)	1.8	1.1	1.8	1.59		1		1.9
Potassium (mg)	11.7	21.5	11.7	21.5	4.5	14	18	10
Potassium (mmol)	0.3	0.55	0.3	0.55		<1		0.3
Magnesium (mg)				4.4	0	0	2.4	
Magnesium (mmol)				0.183				
Calcium (mg)				7.3	0		40	8
Calcium (mmol)				0.183				0.2
Chloride (mg)							32	

4.2 Psychological Aspects

4.2.1 Palatability

It must be recognized that the simple aspect of making a fluid palatable will promote its intake. For example, Szlyk et al (1989) studied the effects of water temperature and flavouring on voluntary dehydration in men, and found that either flavouring or cooling of warm iodinated (16 mg/L) water enhanced fluid intake and reduced body weight deficits.

Similarly Rolls (1994) considers that the taste of the available drinks is a major determinant of the amount consumed. She lists factors that can affect palatability as the cultural background of the individual, previous experience with the drink and the time of the day. Furthermore, for specific individuals, palatability is not constant. Hypohydration can increase the pleasantness of fluids whereas rehydration decreases the pleasantness. This decrease in acceptability can be specific to the particular fluid being consumed. Consequently, Rolls (1994) advises that if the goal is to increase fluid intake, switching to a different drink will help to maintain consumption.

Palatability of fluids is enhanced by the addition of sweeteners (Rolls, 1987) and salt (Burke, 1996). Nevertheless, Davis et al (1988) have shown that the addition of too much sugar can decrease acceptability. In that study trained athletes reported that glucose-electrolyte drinks containing 12% glucose caused significantly more nausea and fullness than either 6% glucose or water.

In a study of reservists consuming field rations during field exercise training, Rose et al (1989) established that fluid intake could be enhanced and consequently, hypohydration could be lessened, by flavouring the field drinking water.

The preferred temperature of a drink also depends on a number of factors including culture and learning and the physiological state of the individual (Rolls, 1994). In a French study when hypohydrated subjects were offered water ranging in temperature from 0°C to 50°C, they drank the most when the water was at 15°C (Boulze et al, 1983), whereas in an American study the preferred water temperature for subjects after exercise was 5°C (Sandick et al, 1984). Hubbard et al (1984) studied the effects of flavour and temperature of fluids on rehydration after a simulated desert march and found that cold (15°C), flavoured, iodinated water elicited over twice the degree of rehydration than when warm (40°C) iodinated water was ingested. Hubbard et al (1984) concluded that the reluctance to drink warm, iodinated water is an example of negative alliesthesia rather than a failure of the thirst mechanism.

Seidman et al (1991) reported that subjects being evaluated on a 30 km outdoor march in the heat found lukewarm drinks to be not very palatable and their consumption of flavoured, sweetened beverages was no more than that of tap water. These authors believe that when carbohydrate drinks can be cooled, they may promote voluntary fluid intake and in turn reduce voluntary dehydration.

4.2.2 Recognition of Product

The proliferation of sports drinks and the common sight of trainers carrying a water bottle to sports participants at seemingly every available opportunity has highlighted the requirement for adequate hydration. The general public is becoming more and more aware of the requirement for hydration. For this reason the addition of a recognisable sports product to the ration pack may aid increased fluid intake.

4.3 Mechanical Aspects

The mechanics of ensuring adequate water intake by soldiers in the field is one aspect that is not covered in the literature. Anecdotal evidence would suggest that the present military issue canteen does not lend itself to easy use when on the move due to the necessity to remove the canteen from its pouch and to unscrew the lid.

DFSC is collaborating with the Army Technology and Engineering Agency (ATEA) and with AMRL -Queensland to investigate improved systems of water delivery.

Two materiel means which could possibly improve delivery and boost fluid intake have been identified. The first is based on a bladder from which fluid can be ingested through a flexible tube. This tube could be located conveniently near the mouth for ease of use. The second item would be a modification of the present canteen based on the type of sports bottle that has a push down cap that can be pulled open with the teeth.

Commercially available sports bottles may not be sufficiently robust for military use. ATEA considers that the top to the present canteen could be remodelled if there was sufficient interest in this concept.

The bladder systems are available commercially under various names eg 'Camelback' and 'Oasis'. The Oasis has two parts, the bladder which is made of a clear plastic and an outer Goretex-like pouch from which the bladder can be extracted for filling. The Oasis is designed for carrying on the back of a rucksack or on a belt but could also be placed within the rucksack. One concern with this product is that the bladder does not appear to be insulated and therefore the fluid may become heated and less palatable. DFSC is conducting temperature profiles at AMRL Queensland on this aspect. ATEA is working on a similar product to the Oasis. This would be bladder that is an integral part of the military issue backpack or is incorporated into a vest. Prototype backpacks containing water bladders have been despatched to AMRL Queensland for temperature profiling.

4.4 Potability Aspects

Of prime importance is the potability of any hydration fluid used by military personnel. Troops in the field are presently supplied with iodine disinfecting tablets. The effectiveness of these tablets in solution can be affected by antagonistic agents, eg Vitamin C. If the hydration source was supplied as a fluid there would be no need for the use of the water purification tablets. Should the hydration source be supplied as a powder for subsequent mixing in iodine treated water, the compatibility of the powder and iodine would need to be assured.

5. Conclusions

1. Adequate consumption of fluids by ADF members working in the heat is a major consideration in preventing dehydration induced heat illness and its associated problems.

2. Fluids containing 4-8% CHO and electrolytes are cleared from the stomach and absorbed at least as readily as water.

3. Hyperhydration prior to engaging in hard physical work in the heat has benefits in attenuating heat stress and may improve performance.

4. Palatability and temperature play a major part in promoting fluid intake.

5. The composition of most sports drinks is satisfactory from a physiological viewpoint.

6. Sports drinks are accepted by the broad community as assisting hydration. As such their efficacy is also likely to be accepted by ADF members.

7. Improved mechanical methods of ingesting water relative to the Defence issue canteen are available and are currently being evaluated.

6. Recommendations

1. Consideration should be given to replacing the current beverage base powder in ration packs with a beverage based on sports drinks.

2. Field acceptability trials to find the most acceptable sports drinks should be conducted.

3. Laboratory trials to assess the influence of sports drinks on the efficacy of water purification tablets should be undertaken.

4. The effectiveness and service suitability of 'bladder' style delivery systems and push/pull tops such as on some sports bottles, in the field should be evaluated.

5. The influence on performance in the heat of chronic hyperhydration should be investigated.

6. Subject to a favourable outcome from recommendation 5 above, techniques for achieving hyperhydration of Defence personnel prior to field exercises in the heat should be considered for inclusion in Defence Instruction PERS 16-9.

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water consumption, water, hydration, dehydration, body fluids, fluids, drinks, heat, heat stress (physiology), illness, absorption (physical), fatigue (physiology), thirst

19. ABSTRACT
Defence personnel working in the heat run the risk of heat illnesses and decreased performance due to hypohydration. Physiological, psychological and mechanical methods for improving the intake and absorption of water into the body are discussed. Recommendations include evaluation of the effectiveness and service suitability of 'bladder' style delivery systems, and water bottles with push/pull tops such as those used on some sports bottles, consideration of the inclusion of 'sports drinks' into ration packs, and studies on hyperhydration.